8.0 EAST SHORE NUTRIENT LOADING

8.1 Description of Study Area

The east shore area runs from the Incline Village region south to the northern edge of Stateline. North to south, the watersheds included in this area are Sand Harbor, Marlette Creek, Secret Harbor Creek, Bliss Creek, Deadman Point, Slaughter House, Glenbrook Creek, North Logan House Creek, Logan House Creek, Cave Rock, Lincoln Creek, Skyland, North Zephyr Creek, Zephyr Creek, and McFaul Creek.

A majority of the land use in this area is vegetated. The residential communities that are in the area are located along the shoreline and extend from Stateline north to Glenbrook. There are also recreational facilities interspersed throughout the area, including a golf course in Glenbrook.

8.2 History of Development

Much of the east shore is undeveloped. The areas of Glenbrook and Zephyr Cove began to develop in the late 1800s. Wild hay was harvested and grain and vegetables were planted in Glenbrook meadow in the 1860s and the community at Glenbrook Bay was established at Walton's Landing in 1861. By 1863, a hotel and way station was established along the Lake Tahoe Wagon Road at Zephyr Cove. The Glen Brook House was constructed in 1866, and the enduring role of Glenbrook as a hostelry and tourist resort began. In the 1930s, George Whittell acquired a continuous strip of property from the Bliss and Hobart estates that stretched from Crystal Bay south to Zephyr Cove. The Bliss family sold their Glenbrook property in the 1970s for the private Glenbrook subdivision. (Lindstrom 2000)

8.3 Local Geology

The basin-fill along the eastern shore of Lake Tahoe is homogenous. It is composed of decomposed granitic material ranging is size from boulders and cobles down to fine sand. The homogenous nature of the fill leads to a relatively high hydraulic conductivity. The hydraulic conductivity is estimated to range from 3 to 46 m/day (10 to 151 ft/day), with the average around 24 m/day (79 ft/day).

The majority of the eastern shore consists of outcroppings of granitic rock. Thin strips of basin fill are dispersed along the shoreline. There is a limited amount of well logs for the eastern shore. Well logs in the Zephyr Cove area display the depth of fill extending to 15 meters bgs (50 ft). The rest of bedrock depth along the eastern shoreline is shallow. In some areas bedrock could be as deep as 4.5 meters (15 ft) and the average is most likely around 2.4 meters (8 ft). There are some faults along the Eastern Shore that could have an influence on groundwater recharge. For example, the Sand Harbor fault, Marlette Creek fault, Slaughterhouse Canyon fault have been identified in the area (Schweicker and others). These faults intersect the shoreline in a Northeast-Southwest direction.

The length of the shoreline representing groundwater recharge for the eastern shoreline extends from the Incline Village Watershed south to the state line in South Lake Tahoe. The majority of the shoreline is granitic outcrops. The total of the length of basin-fill dispersed along the shoreline is approximately 10,140 meters (6.3 miles).

8.4 Previous East Shore Investigations

8.4.1 Thodal 1995

Thodal conducted a study of groundwater quality in the Douglas County and Carson City area of the Lake Tahoe Basin, Nevada. He compiled data from the State of Nevada as well as collecting additional data as part of the study from 1985 through 1987. The purpose of the study was a reconnaissance investigation of groundwater and groundwater quality in this region. The objective was to compile existing geophysical, hydrogeologic, and water quality data and to collect additional data to describe the hydrogeologic setting and groundwater quality characteristics. Thodal found that the range of total dissolved nitrogen was <0.01 mg/L to 9.3 mg/L. The range of total dissolved phosphorus was found to be <0.005 mg/L to 0.065 mg/L.

8.4.2 USGS & Nevada Bureau of Health Protection Services Water Quality Monitoring

There are twenty-six wells located in the East Shore region. A majority of these wells are located near Zephyr Cove and Glenbrook. Most of the wells are located near the shore as the basin fill aquifer along the East Shore is typically limited to the near shore area. Data has been collected for fifteen wells; six of which have been sampled more than once. The wells are public drinking water wells, private drinking water wells or monitoring wells. Nutrient data has been collected periodically since 1986. See Section 8.5, Nutrient Concentrations for a detailed description of the nutrient data. Table 8-1 includes construction information for those wells with monitoring data.

Table 8-1. East Shore Area Well Construction Information

Site No.	Elevation (ft above msl)	Depth of Well	
		Meters	(Feet)
190	6240	10	(32)
189	6245	5	(17)
191	6230	2	(8)
192	6245	5	(18)
187	6240	7	(22)
179	6390	55	(180)
185	6280	61	(200)
162	6270	8	(27)
160	6235	9	(30)
163	6240	10	(32)
154	6230	33	(109)
167	6340	6	(20)
168	6260	3	(9)

Site No.	Elevation (ft above msl)	Depth of Well	
		Meters	(Feet)
173	6232	2	(7)
171	6230	34	(110)

Notes:
1. The source agency code associated with each site number can be found in Appendix A.
2. -- indicates the elevation or well depth is unknown.
3. Data obtained from USGS, TRPA, Nevada BHPS, Nevada DWR.

8.5 Nutrient Concentrations

TRPA requires Glenbrook golf course to collect groundwater samples. Edgewood has not reported monitoring data to TRPA, however, the USGS has several wells located on the golf course property. The USGS regularly monitors five wells along the east shore. Ten additional wells have been sampled for at least one event. The USGS samples for dissolved ammonia, dissolved Kjeldahl Nitrogen, dissolved nitrate plus nitrite, dissolved orthophosphorus and total dissolved phosphorus. The Bureau of Health Protection Services requires sampling for nitrate and nitrite in drinking water wells. Limited data was available from the BHPS. The average concentrations of each constituent are listed in Table 8-2.

The dissolved ammonia + organic nitrogen concentrations range from 0.02 mg/L to 1.5 mg/L, averaging 0.471 mg/L. The dissolved nitrate concentrations, which include nitrite, range from 0.004 mg/L to 10 mg/L with an average of 0.658 mg/L. This results in an average total dissolved nitrogen concentration of 1.129 mg/L.

Orthophosphorus concentrations for well 041 range from 0.001 mg/L to 0.255 mg/L, averaging 0.022 mg/L. The range of total dissolved phosphorus is 0.003 mg/L to 0.26 mg/L, averaging 0.031 mg/L.

A cluster of wells is located near Zephyr Resort (Figure 8-3). These wells show an increase in total nitrogen concentration downgradient. The land use is primarily recreational. An active sewer line runs through the area. The phosphorus concentrations are constant throughout the area. Another grouping of wells is located within the Glenbrook golf course (Figure 8-1). Two wells are monitored regularly while the third has only two monitoring events associated with them. Again there is an increase in total nitrogen downgradient. This concentration may influenced by the golf course and a sewage line in the area. Residential land use is located upgradient of the golf course and could also be contributing to nutrients. A change in nutrient concentration in the downgradient direction cannot be assessed for the remainder of the wells. The wells located in the undeveloped areas show a higher total nitrogen concentration than those in the residential neighborhoods. The natural nitrogen concentration in this area may be significant.

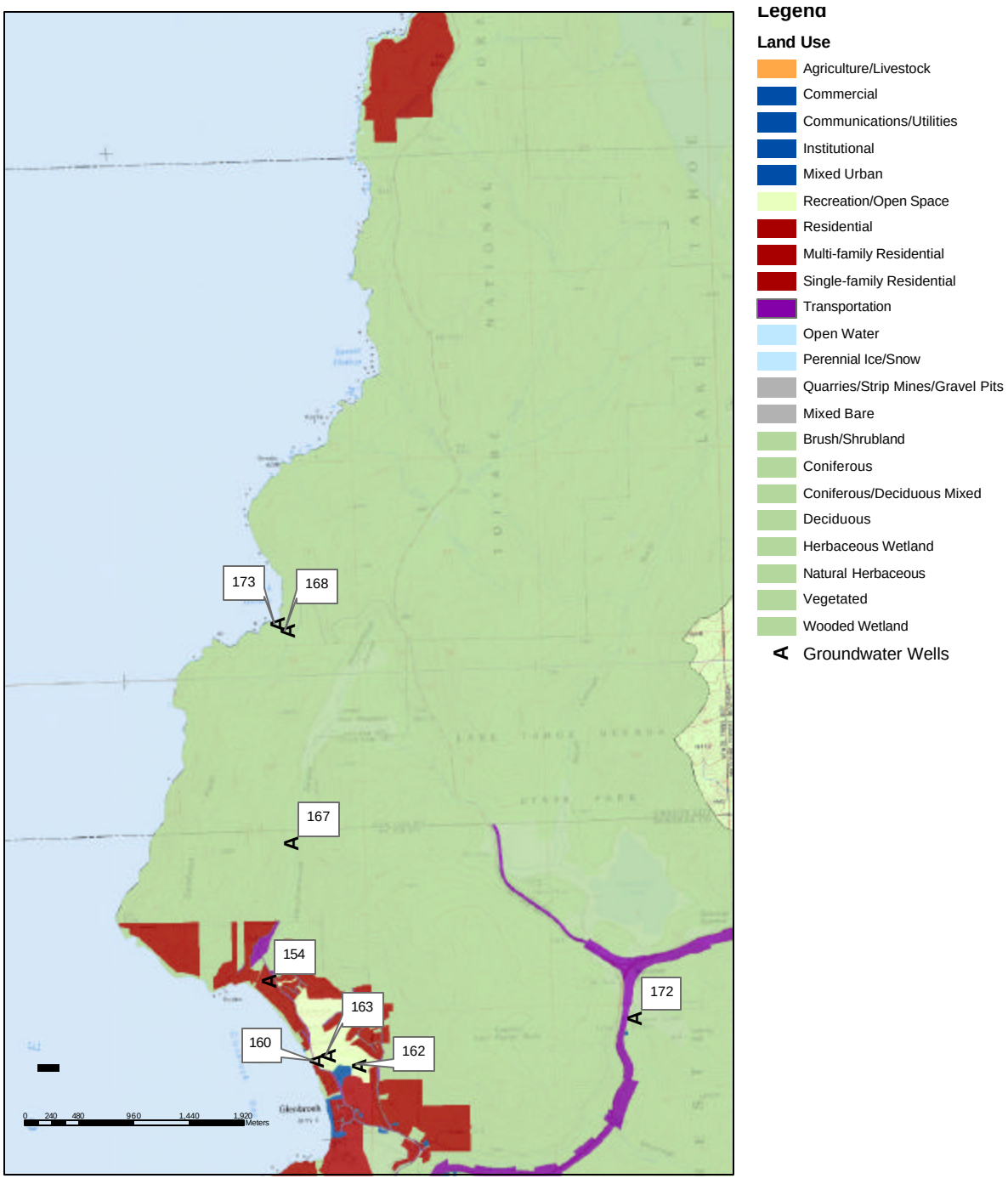
Table 8-2. East Shore Average Nutrient Concentration (mg/L)

	Well ID				
Constituent	190	189	191	192	187
Ammonia + Organic	0.179	0.700	1.500	1.000	1.000
Nitrate	6.974	0.027	0.099	0.136	0.010
Total Nitrogen	7.153	0.727	1.599	1.136	1.010
Orthophosphate	0.016	0.010	0.020	0.001	0.001
Total Phosphorus	0.037	0.005	0.005	0.005	0.005
Top of Open Interval (ft bgs)	<32	<17	<8	<18	<22
	Well ID				
Constituent	179	185	162	160	163
Ammonia + Organic	0.073	0.300	0.148	0.174	0.125
Nitrate	0.244	0.290	0.049	1.438	0.218
Total Nitrogen	0.317	0.590	0.197	1.613	0.343
Orthophosphate	0.005	0.010	0.068	0.039	0.024
Total Phosphorus	0.024	0.010	0.081	0.070	0.035
Top of Open Interval (ft bgs)	<180	50	<27	<30	<32
	Well ID				
Constituent	154	167	168	173	171
Ammonia + Organic	0.200	0.600	0.400	0.600	0.070
Nitrate	0.100	0.063	0.162	0.034	0.018
Total Nitrogen	0.300	0.663	0.562	0.634	0.088
Orthophosphate	0.030	0.022	0.016	0.033	0.034
Total Phosphorus	0.040	0.034	0.031	0.040	0.046
Top of Open Interval (ft bgs)	<109	<20	<9	<7	52

Notes:

1. All concentrations reported are dissolved.
2. Data obtained from USGS, BHPS
3. Top of Open Interval with a – indicates the open interval is unknown. A < indicates less than the total depth of the well.
4. Nitrate concentrations include nitrite
5. Total nitrogen concentration is calculated by adding ammonia + organic + nitrate
6. na – not analyzed

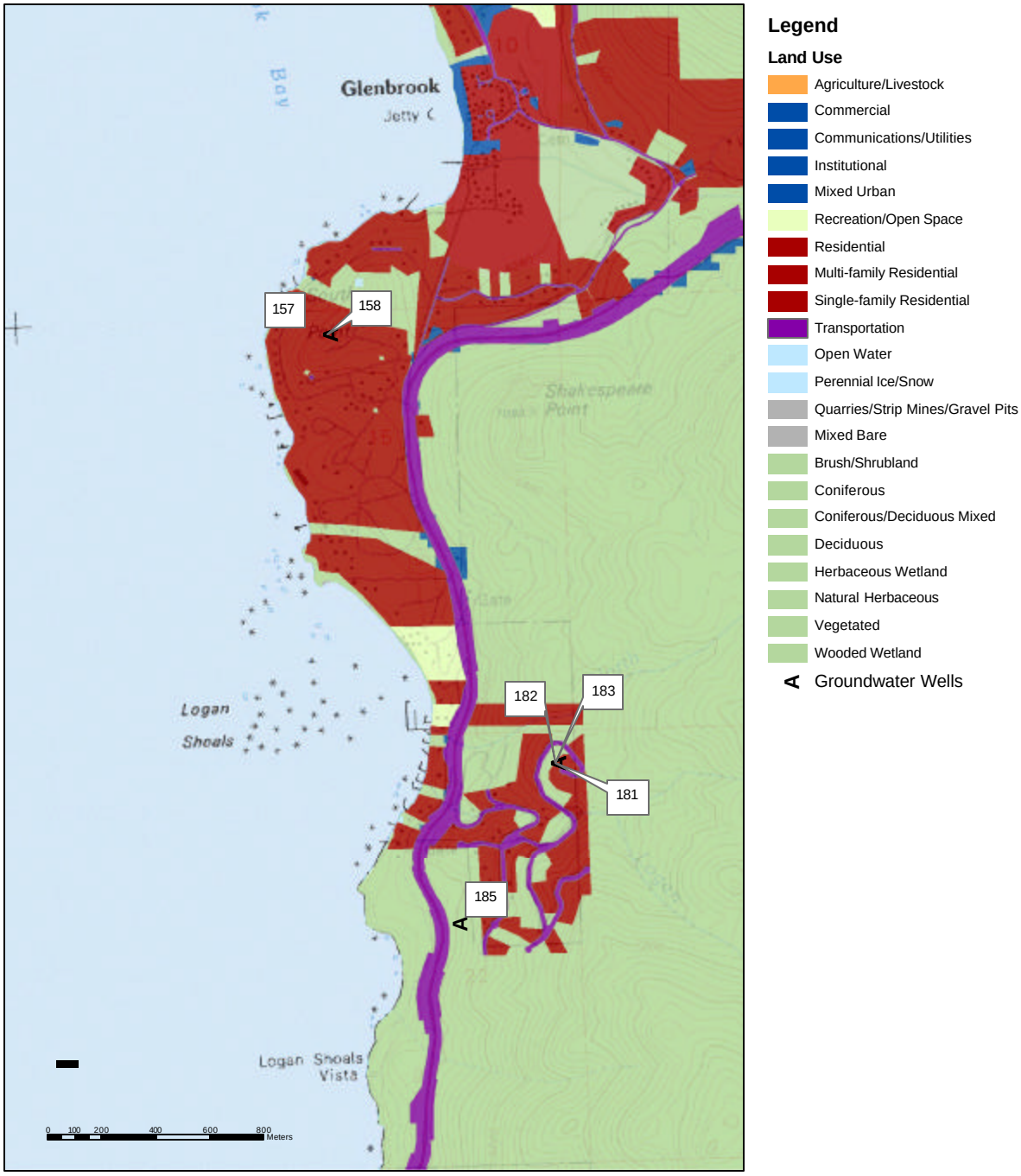
Figure 8-1. East Shore (North) Groundwater Wells and Land Use



Notes:

1. Land Use coverage provided by Tahoe Research Group.
2. Only wells with groundwater elevation and/or analytical data are shown.

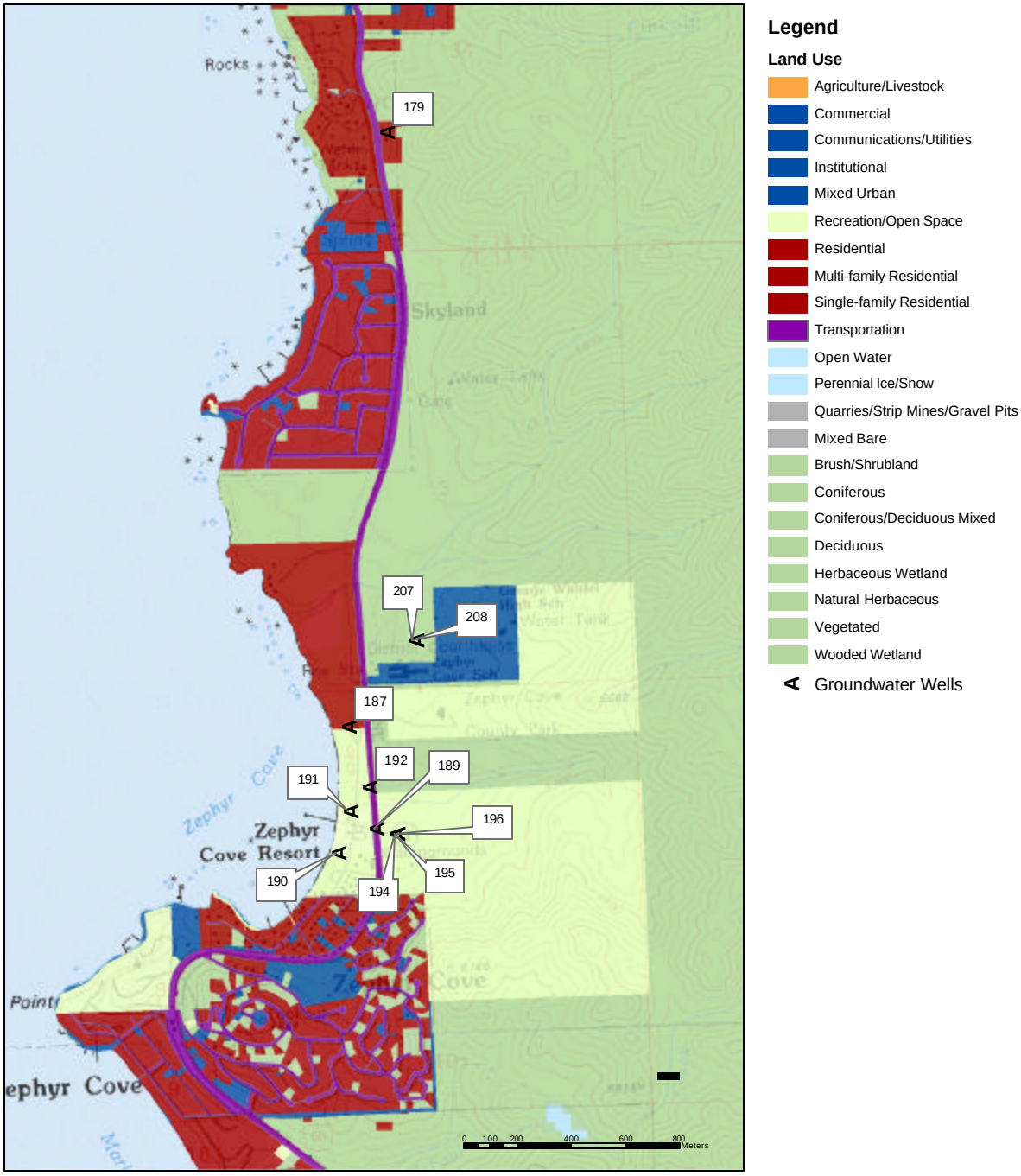
Figure 8-2. East Shore (Central) Groundwater Wells and Land Use



Notes:

1. Land Use coverage provided by Tahoe Research Group.
2. Only wells with groundwater elevation and/or analytical data are shown.

Figure 8-3. East Shore (South) Groundwater Wells and Land Use



Notes:

1. Land Use coverage provided by Tahoe Research Group.
2. Only wells with groundwater elevation and/or analytical data are shown.

8.6 Groundwater Discharge

No seepage meter measurements have been taken in this area. This limits the discharge calculation to the Darcy's Law approach.

A simple Darcy's Law calculation can be executed using the average gradient, median hydraulic conductivity and aquifer area. The average hydraulic gradient is 0.012. The median hydraulic conductivity, 24 m/day (79 ft/day) as determined from the boring logs and was used. The length of the basin fill aquifer is estimated at 10,140 meters (6.3 miles). A depth of 2.5 to 4.5 meters (8 to 15 feet) represents the average depth of basin fill deposits.

The calculation yields an estimated discharge rate of 2.7×10^6 to 4.8×10^6 m^3/day (2,200 to 3,900 acre-ft/year).

8.7 Nutrient Loading

The potential range of nutrient discharge from the East Shore area occurring as direct groundwater inputs to Lake Tahoe was calculated by multiplying the estimates of annual groundwater discharge by concentrations of nutrients found in monitoring wells. The method of using the land use weighted average is not used in this region, as most of the wells are positioned to accurately reflect the land uses of the region. Details of the methodology used are described in Section 3.2.

The average nutrient concentrations are multiplied by the groundwater flux estimates calculated in Section 8.6. Table 8-3 summarizes the nutrient flux using this method. This approach neglects the accumulation of nutrients as groundwater progresses downgradient through potential sources.

The downgradient approach is the most applicable to this area. All wells except 162, 167 and 189, were used in the downgradient average estimation. Many of the wells are placed along the lake shore. This is primarily due to the basin fill deposits being limited to the shoreline area. These wells are also located in representative land use designations. This provides an estimate for a range of sources and allows for the accumulation of nutrients.

The downgradient average and discharge estimate of 4.8×10^6 m^3/day (3,900 acre-feet/year) are used in the basin-wide estimate for overall nutrient loading to Lake Tahoe. The downgradient average was chosen to best represent the nutrient concentrations that are likely in this region. The wells are placed to represent much of the land use along the East Shore as well as show provide a concentration which represents either accumulation or degradation of nutrients.

Table 8-3. East Shore Average and Downgradient Annual Nutrient Loading

Constituent	Groundwater Flux (m^3/year)	Average Concentration Method		Downgradient Concentration Method	
		Average Concentration (mg/L)	Nutrient Loading (kg/yr)	Downgradient Average Concentration (mg/L)	Nutrient Loading (kg/yr)
Ammonia + Organic	2.7E+06		1,279		1,271
	4.8E+06	0.471	2,267	0.468	2,253
Nitrate	2.7E+06		1,784		2,199
	4.8E+06	0.658	3,163	0.810	3,898
Total Nitrogen	2.7E+06		3,063		3,470
	4.8E+06	1.129	5,430	1.279	6,151
Orthophosphate	2.7E+06		59		51
	4.8E+06	0.022	105	0.019	91
Total Phosphorus	2.7E+06		85		79
	4.8E+06	0.031	150	0.029	140

Notes:
1. 1 m^3/year = 0.0008 acre-feet/year, 1 kg/yr = 2.2 lb/yr
2. Average nutrient concentrations are derived from those included in Table 8-2.

8.8 Ambient Nutrient Loading

Ambient loading was calculated from the basin-wide data set for wells located in a forested land use. The ambient nutrient loading is calculated to estimate the amount of nutrients that would discharge into Lake Tahoe regardless of anthropogenic sources. The discharge rates which were determined to be the most reasonable estimates of groundwater discharge were used in calculating the ambient nutrient loading. Based on these estimates, the total dissolved nitrogen concentrations that may be entering the lake from natural processes is 871 kg/year (1,920 lbs/yr). The estimated ambient total dissolved phosphorus concentration entering the lake is 327 kg/year (721 lbs/yr). Table 8-4 summarizes the loading estimates.

Table 8-4. East Shore Ambient Nutrient Loading Estimate

	Groundwater Discharge (m^3/year)	Ambient Total Dissolved Nitrogen (mg/L)	Ambient Total Dissolved Phosphorus (mg/L)	Ambient Nitrogen Nutrient Loading (kg/year)	Ambient Phosphorus Nutrient Loading (kg/year)
Incline Village	4.81E+06	0.181	0.068	871	327

Notes:
1. 1 m^3/year = 0.0008 acre-feet/year, 1 kg/yr = 2.2 lb/yr
2. Average nutrient concentrations derived from those included in Section 3.2.

8.9 Summary & Conclusions

The east shore area contributes a significant amount of groundwater to the lake each year. This is primarily due to the higher hydraulic conductivities found here as well as the steeper gradient.

The hydrogeologic setting along the east shore of Lake Tahoe is characterized by fractured bedrock with a weathered zone. Unlike the west shore where glaciers have scoured off much of the weathered material, this weathering rind appears to play a significant role in ground water flow and storage. Studies are required to define the hydrologic significance of the weathered zone, how groundwater interacts and flow through this zone, and to what extent do fractures play in groundwater flow. To collect this data, detailed ground water investigations, geologic (structural) analyses, and surface geophysical investigations should be conducted. The geometry of the sedimentary fill below this length of shoreline is significantly different from other portions of the basin, but the data defining these differences is sparse. Additional geology information would reduce errors in the loading estimate.

To assist in determining the actual source(s) of nutrients, several methods could be used. The IKONOS data could be used to determine if any neighborhoods have a significant number of fertilized lawns. These areas could be targeted for additional monitoring. Historical record searches could be performed to locate and study the residual effects of septic systems. The infiltration basins of the region should also be monitored to determine their potential threat to elevated nutrient concentrations in groundwater.

The results of the East Shore area nutrient loading estimate are compared to those presented in The U.S. Forest Service Watershed Assessment (Murphy et al. 2000), Table 8-5. Comparing these values, the East Shore area represents 10.3% of the nitrogen and 3.5% of the phosphorus nutrient loading from groundwater to Lake Tahoe.

Table 8-5. East Shore Area Groundwater Nutrient Loading Comparison to Basin Wide Loading Estimates from U.S. Forest Service Watershed Assessment (Murphy et al. 2000)

	Nitrogen	Phosphorus	Dissolved Phosphorus
U.S. Forest Service Watershed Assessment Results, Basin-Wide			
Estimated annual nutrient loading from all sources (kg)	418,100	45,700	17,000
Estimated annual nutrient loading from groundwater (kg)	60,000	4,000	4,000
Corps Groundwater Evaluation Results, East Shore Area			
Estimated annual nutrient loading from groundwater (kg)	6,151	140	140
Estimated percent of annual nutrient loading from all sources	1.5%	0.3%	0.8%
Estimated percent of annual nutrient loading from groundwater	10.3%	3.5%	3.5%

Comparing the total groundwater nutrient loading (Table 8-3) to the ambient nutrient loading (Table 8-4), natural processes may make up to 14% of the nitrogen and 100%+ of the total dissolved phosphorus loading to the lake. These results indicate that the total phosphorus loading may be coming from natural sources in the East Shore area.

Glenbrook and Zephyr Cove tend to have elevated concentrations of nitrogen. These two areas warrant further investigation into the source and behavior of the nitrogen in the region. A likely source in Glenbrook is the fertilizer used as part of golf course activities. Also nearby are active sewage conveyance systems. This system could also be a source of nitrogen to the groundwater. An evaluation of the actual source of nitrogen should be investigated and mitigated in this region. The Zephyr Cove area also contains active sewage conveyance lines in the vicinity. An infiltration basin is located upgradient of well 191 and could be contributing to the nitrogen concentrations in the groundwater. This area should be further evaluated to determine the primary source of nitrogen.